CLAIMS

1. A method of controlling a heap leach process through controlling an irrigation rate of a heap as a function of at least one of an aeration rate of the heap, a determination of advection at least at one predetermined point in the heap, and a determination of temperature at least at one predetermined point in the heap, and controlling an aeration rate of the heap as a function of a determination of the oxidation rate of material within the heap.

2. A method as claimed in claim 1, in which aeration of the heap is by natural convection.

3. A method as claimed in claim 2 in which the natural convection is at least partly induced.

4. A method as claimed in claim 1 in which the aeration is forced.

5. A method as claimed in any one of claims 1 to 4, which includes determining the advection at or below the heap surface.

6. A method as claimed in claim 5, which includes determining the advection at a point from 0% to 95% of the heap height below the heap surface.

7. A method as claimed in claim 6, which includes determining the advection at a point from 1% to 40% of the heap height below the heap surface.

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8. A method as claimed in claim 7, which includes determining the advection at a point from 2% to 30% of the heap height below the heap surface.

9. A method as claimed in claim 1 to 8, which includes controlling the aeration rate to maintain a predetermined oxygen utilization of the heap.

10. A method as claimed in claim 9, which includes maintaining the oxygen utilization of the heap in the range of 1% to 99%.

11. A method as claimed in claim 10, which includes maintaining the oxygen utilization of the heap in the range of 15% to 90%.

12. A method as claimed in claim 11, which includes maintaining the oxygen utilization of the heap in the range of 20% to 85%.

13. A method as claimed in any one of the previous claims, which includes maintaining the average aeration rate and average irrigation rate at a ratio in the range of 0.125:1 to 5:1.

14. A method as claimed in claim 13, which includes maintaining the average aeration rate and average irrigation rate at a ratio in the range of 0.15:1 to 2:1.

15. A method as claimed in claim 14, which includes maintaining the average aeration rate and average irrigation rate at a ratio in the range of 0.175:1 and 1.5:1.

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16. A method as claimed in claim 15, which includes maintaining the average aeration rate and average irrigation rate at a ratio of about 0.2:1.

17. A method as claimed in any one of the previous claims, which includes maintaining the instantaneous aeration rate and instantaneous irrigation rate at a ratio in the range of 0:1 to 5:1.

18. A method as claimed in claim 17, which includes maintaining the instantaneous aeration rate and instantaneous irrigation rate at a ratio in the range of 0:1 to 2:1.

19. A method as claimed in claim 18, which includes maintaining the instantaneous aeration rate and instantaneous irrigation rate at a ratio in the range of 0:1 and 1,5:1.

20. A method as claimed in claim 19, which includes maintaining the instantaneous aeration rate and instantaneous irrigation rate at a ratio of about 0.2:1.

21. A method as claimed in any one of the previous claims, which includes determining the temperature below the heap surface.

22. A method as claimed in claim 21, which includes determining the temperature at a point from 1% to 95% of the heap height below the heap surface.

23. A method as claimed in claim 22, which includes determining the temperature at a point from 5% to 50% of the heap height below the heap surface.

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24. A method as claimed in claim 23, which includes determining the temperature at a point from 10% to 30% of the heap height below the heap surface.

25. A method as claimed in any one of claim 1 to 20, in which the temperature determination includes a determination of the pregnant leach stream temperature.

26. A method as claimed in any one of claims 1 to 24 in which the oxidation rate of sulphide material is determined as a function of any one or more of determinations of the oxygen content of the heap gas, the pregnant leach stream temperature, the heap temperature, the pregnant leach stream metal content, the pregnant leach stream redox value, the pregnant leach stream oxygen concentration, the heap oxygen uptake rate, the heap carbon dioxide uptake rate, simulation based on at least feed composition, sulphide mineral leaching rates, heap geometry, climatic conditions external to the heap, and historical values of previously leached heaps.

27. A method as claimed in claim 26 in which the pregnant leach stream metal content includes recovered metal content.

28. A method of increasing the temperature of heap of material for heap leaching by:

a) equipping a support surface for the heap with aeration and drainage equipment;

b) forming a layer of granular material on the support surface,

c) installing an irrigation system proximate the operatively upper surface of the layer of granular material,

d) forming a layer of ore on the granular material layer;

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e) passing a hot solution through the granular layer by means of the irrigation system to heat the granular layer,

f) blowing ambient air through the aeration equipment of the support surface to react with the layer of ore until the temperature of the ore heap reaches a predetermined take-off point,

g) at least reducing the hot solution irrigation flow of step e) through the granular layer,

h) introducing irrigation of the ore layer and adjusting the aeration through the aeration equipment until a predeterminable normal optimum heap temperature is reached, and

i) controlling the heap leaching process according to any one of claims 1 to 27.

29. A method as claimed in claim 28 in which step d) includes inoculation of the layer of ore with suitable microorganisms and at least some acid.

30. A method as claimed in claim 28 or 29 in which the granular layer is formed from crushed rock.

31. A method as claimed in claim 28 to 30 in which the hot solution includes at least one of hot pregnant leach solution, hot solvent extraction raffinate, water, or other fluid.

32. A method as claimed in any one of claims 1 to 31 which includes determining an optimum heap configuration for a bio-assisted heap leach process of an ore heap; by measuring the leaching rate, the heat of reaction, and the sulphide content of the ore; and determining maximum aeration and irrigation rates and an optimum heap height.

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33. A method as claimed in any one of the preceding claims including introduction of microorganisms into the heap of material comprising:

a) preparing microorganisms substantially without exopolymers on their external cell walls;

b) adding microorganisms prepared according to step a) to the heap;

c) at least one of un-assisted or assisted re-activation of the microorganisms in the heap to produce exopolymers on their external cell walls.

34. A method as claimed in claim 33 in which step a) includes exposing the microorganisms to a low nutrient environment or starving the microorganisms.

35. A method as claimed in claim 34 in which the microorganisms are starved by limiting the amount of carbon available to the microorganisms.

36. A method as claimed in any one of claims 33 to 35 in which step b) includes one or more of adding microorganisms to the heap during formation thereof, drip irrigation of the heap, sprinkling of the heap, and pressurized irrigation of the heap.

37. A method as claimed in any one of claims 33 to 36 in which the assisted re-activation comprises exposing the microorganisms to a nutrient rich environment.

38. A method as claimed in claim 37 in which the microorganisms' environment is enriched by means of at least one of:

a) embedding solid nutrients in the heap;

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b) irrigating the heap with a nutrient rich solution;

c) aerating the heap with a nutrient rich gas; and

d) aerating the heap with a gas enriched in carbon dioxide.

39. A method as claimed in claim 38 in which includes the step of embedding a carbon source in the heap.

40. A method as claimed in claim 39 in which the carbon source comprises carbonate.

41. A method as claimed in claims 38 in which the solid nutrients of step a) comprise slow release nutrients.

42. A method as claimed in claim 38 in which the gas of the step c) is enriched with one or more of a nutrient aerosol and ammonia.

43. A method as claimed in any one of claims 33 to 42 in which the un-assisted re-activation includes re-activation due to one or more of prevalent conditions in the heap and natural gas flow through the heap.

44. A method as claimed in claim 43 in which the natural gas includes carbon dioxide.

45. A method according to any one of claims 1 to 32 which includes the step of enriching the environment of microorganisms embedded in a heap of material for bio-assisted heap leaching by means of:

a) embedding solid nutrients in the heap:

b) irrigating the heap with a nutrient rich solution;

c) aerating the heap with a nutrient rich gas; and

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d) aerating the heap with a gas enriched in carbon dioxide

46. A method as claimed in claim 45 which includes embedding a carbon source in the heap.

47. A method as claimed in claim 46 in which the carbon source comprises carbonate.

48. A method as claimed in claims 45 in which the solid nutrients of step a) comprises slow release nutrients.

49. A method as claimed in claim 45 in which the gas of the step c) is enriched with one or more of a nutrient aerosol and ammonia.

50. A method as claimed in any one of claims 1 to 32 and 33 to 49 in which a sulphide fuel material is added to the heap during stacking thereof.

51. A method as claimed in claim 50 in which the sulphide fuel includes pyrite or other suitable sulphide concentrate.

52. A method as claimed in any one of the preceding claims in which irrigation is applied intermittently.

53. A method as claimed in claims 4 to 52 in which aeration is intermittently forced through the heap.

54. A method as claimed in any one of claims1 to 32 in which the heap is divided into at least two zones and the process is at least partly independently controlled in each zone.

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55. A method substantially as herein described with reference to Example 1 and Figures 21 to 24.

56. A method substantially as herein described with reference to Example 2 and Figures 21 and 25 to 27.

57. A method substantially as herein described with reference to Example 3 and Figures 21 and 28 to 30.

58. A method substantially as herein described with reference to Example 4 and Figure 31.

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